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PRINCIPAL INVESTIGATOR: James P. Delany, Ph.D.

CONTRACTING ORGANIZATION: Louisiana State University A&M College
Baton Rouge, Louisiana 70808

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6. AUTHOR(S)
James P. DeLany, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Louisiana State University A&M College
Baton Rouge, Louisiana 70808

E-MAIL:
delanyjp@mhs.pbrc.edu

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13. ABSTRACT *(Maximum 200 Words)*
The objective of the current study is to define a range of energy requirements of servicewomen, defining the variation as it relates to jobs, military settings, and activity patterns. This is crucial information needed not only for determination of nutritional requirements for energy balance, but specific nutrient density standards for servicewomen. Total daily energy expenditure is measured using the doubly labeled water (DLW) method. Activity patterns from actigraphs will be analyzed for hours of sleep, description of job/work patterns by examining bursts of concerted activity versus steady activity. Energy requirements for men have been better established and will serve to anchor the results obtained in women to previously established norms in men. The first field study was conducted at Fort Bragg/Camp Mckall during a Combat Support Hospital training exercise. Very high energy expenditures were observed during the Crucible studies in Marine Recruits. The Shipboard study was carried out in February of 2000. The Marine Basic Training Study was originally planned to occur during the Summer of 2000, but had to be delayed until the Spring of 2001. Planning for the final study, a basic training study at Fort Jackson, is planned for the Summer of 2001.

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4. INTRODUCTION

Women comprise 12.3% of the U.S. military active duty personnel, or approximately 200,000 servicewomen (as of June 30, 1993) (1). This is a significant number even compared to the 1,518,752 active duty men in military service, yet nutritional requirements of women have been far less studied than for men.

Energy Requirements in Women

Although energy requirements of male soldiers have been and continue to be assessed by our labs (USARIEM and PBRC) and others under several environmental and training conditions using the doubly labeled water (DLW) method, energy requirements of female military personnel have not been studied.

Several studies which have included a subset of female subjects, have examined nutrient intake, which may give some idea of energy requirements. A recent assessment of intake was made in 49 Army women by a visual estimation method during an 8-week cycle of the Army Basic Combat Training course (2). Reported intake was 2592±500 kcal/d, which was within the range of energy intakes of 2000 - 2800 kcal/d for female soldiers ages 17-50 years old as defined by the Military Recommended Dietary Allowances MRDA (3). However, the range of intakes ranged from a low of 1294 to a high of 4388 kcal/d. Some of this is certainly due to errors in estimating energy intake, while some is due to true variations in intake. Energy deficit based on body composition changes averaged 180 kcal/d suggesting energy expenditures as high as 2800 kcal/d (4). Consumption of several micronutrients were less than adequate. Vitamin B_6 (76%), Folic acid (65%), calcium (73%), zinc (73%) and iron (90%) were each consumed at levels lower than that of the MRDA. These inadequate intakes point to a potential problem women may encounter when consuming military field rations. The nutrient density of these rations was designed with the higher energy requirements of males. A female recruit consuming meal ready to eat (MRE)s at an expenditure level of 2400 kcal/d would need to consume 131% of energy requirements to meet her daily needs for calcium and as high as 166% of energy requirements to meet her daily needs of iron. It may be necessary to supplement the rations with specific micronutrients to be used by those with lower energy intake requirements or design specific rations for smaller women soldiers.

The objective of the current study is to define a range of energy requirements of servicewomen, defining the variation (with adjustments made for body size/composition) as it relates to jobs, military settings, and activity patterns. This is crucial information needed not only for determination of nutritional requirements for energy balance, but specific nutrient density standards for servicewomen. This will address the first and third specific nutrition topics of the IOM report. Total daily energy expenditure will be measured using the doubly labeled water (DLW) method. As part of the DLW method, total water turnover can be calculated from deuterium elimination and total body water. Corrections are made for atmospheric water exchange, metabolic water and isotopic fractionation. From these calculations we can estimate actual fluid consumption in the field (the second nutrition topic) and fluid requirements during specific categories of jobs and tasks (third nutrition topic). Activity patterns from actigraphs will

be analyzed for hours of sleep, description of job/work patterns by examining bursts of concerted activity versus steady activity. Activity patterns will also be assessed using a boot insert which measures locomotory activity and voluntary energy expenditure. Men will also be studied in many of these settings. Energy requirements for men have been better established and will serve to anchor the results obtained in women to previously established norms in men (or confirm the validity of significant deviations also observed in the female data). We hypothesize that in some settings, there may be smaller differences between genders (normalized for fat free mass (FFM)) than in Army basic training, if absolute rather than relative, or ability group standards are emphasized. Such a finding would help demonstrate and explain a wider possible variation in female energy requirements.

5. BODY

TECHNICAL OBJECTIVES

KEY OBJECTIVES

I. Define energy expenditure in servicewomen in various military settings.

II. Determine if differences in total daily energy expenditure (TDEE) are explained primarily by differences in body size and fat-free mass after differences in activity patterns (locomotory and by wrist-worn actigraphy) are accounted for.

III. Determine if the same holds true for differences between typical men, small men, and women.

IV. Test methods which may be useful in prediction of TDEE.

V. Assess hydration status of men and women by deuterium turnover (part of DLW).

VI. Compare TDEE assessed by footstrike monitor to DLW.

   A. Laboratory study: Demonstrate that the foot contact monitor (FCM) method provides valid estimates of the loco in military-eligible women over a full range of walking and running speeds, regardless of the phase of the menstrual cycle.

   B. Field study: Establish the validity of estimates of total daily energy expenditure (estimated TDEE), calculated from FCM determinations of loco and resting metabolic rate, in female soldiers engaged in military training at the Marine Corps Mountain Warfare Training Center (MCMWTC), Bridgeport, California. The doubly labeled water measurements of TDEE will serve as a reference standard (measured TDEE).

We hypothesize that estimates of total daily energy expenditure of women soldiers in the field (estimated TDEE) will provide valid estimates of actual TDEE (measured TDEE). Valid estimates of TDEE by the Foot Contact Monitor/Resting Metabolic Rate method would suggest that minute-to-minute loco data can be used to estimate macronutrient requirements associated with military training in mountainous terrain. This type of information is urgently needed to improve the match between macronutrient demand and macronutrient availability from rations and body energy stores.

STATEMENT OF WORK

Technical Objective: Determination Of Total Daily Energy Requirements, Water Turnover, and Activity Patterns of Servicewomen in Various Military Settings and Jobs

I. Months 1-2: Preparation Phase
   A. Protocol Development
   B. Contact and clearly define FTXs
   C. Hire/Train Personnel
   D. Order DLW dose for first year
   E. Order Actigraphs and components for Foot Contact Monitor
   F. Principal Investigators Meet to discuss and refine protocols

II. Months 6-18: Army Basic Training Field Study
   A. Coordination Trip
   B. Recruitment Trip
   C. DLW dose preparation and shipment
   D. Study team arrive and set up for field study
   E. Conduct Energy Expenditure and Activity Pattern Study
   F. Study team ship back equipment and samples
   G. Isotope Analyses
   H. Report Preparation

III. Months 11-23: Marine Basic Training Field Study
   A. Coordination Trip
   B. Recruitment Trip
   C. DLW dose preparation and shipment
   D. Study team arrive and set up for field study
   E. Conduct Energy Expenditure and Activity Pattern Study
   F. Study team ship back equipment and samples
   G. Isotope Analyses
   H. Report Preparation

IV. Months 16-28: Mountain Warfare Training Field Study
   A. Coordination Trip
   B. Recruitment Trip
   C. DLW dose preparation and shipment
   D. Study team arrive and set up for field study
   E. Conduct Energy Expenditure and Activity Pattern Study
   F. Study team ship back equipment and samples
   G. Isotope Analyses
   H. Report Preparation

V. Months 20-32: Shipboard Field Study
   A. Coordination Trip
   B. Recruitment Trip
   C. DLW dose preparation and shipment
   D. Study team arrive and set up for field study
   E. Conduct Energy Expenditure and Activity Pattern Study
   F. Study team ship back equipment and samples
   G. Isotope Analyses
   H. Report Preparation

VI. Months 25-36: Army Units Field Study
   A. Coordination Trip
   B. Recruitment Trip
   C. DLW dose preparation and shipment
   D. Study team arrive and set up for field study
   E. Conduct Energy Expenditure and Activity Pattern Study
   F. Study team ship back equipment and samples
   G. Isotope Analyses
   H. Report Preparation

VII. Months 34-36
   Prepare Final Report

SUMMARY OF PROGRESS

I. Months 1-2: First field training study identified, protocol developed, Personnel hired and trained, DLW dose water ordered, actigraphs ordered. We delayed purchasing new foot contact monitors as a new, improved version was being developed that is attached to the boot externally, so that we no longer have to have a custom boot insert made for the monitor. Therefore, for the first field training study, we used some of the old version that Reed Hoyt had on hand. We also delayed the validation study of the FCMs until the new version was received.

II. Months 6-18: The first field study was conducted at Fort Bragg/Camp Mckall, NC, in a Combat Support Hospital field study. Isotope analyses and energy expenditure calculations have been completed. Actigraph data are being analyzed.

III. Months 11-23: We were very fortunate that the opportunity arose to conduct energy expenditure studies in Marine Recruits undergoing the grueling Crucible event conducted at Parris Island, South Carolina. The USARIEM group was asked to conduct cold weather studies in January and February, and I was able to join the team as this project fit perfectly with the aims of this grant.

IV. Months 16-28:

A. We began the process of working out the details of our shipboard activities. We are working with W. Keith Prusaczyk, M.S., Ph.D., a Research Physiologist at the Naval Health Research Center in San Diego, California. A meeting occurred in San Diego, with Cathleen Kujawa, Jim Hodgdon, Dr. DeLany from PBRC and Dr. Beverly Patton from USARIEM where initial details were be worked out.

B. There were discussions about the possibility to conduct studies during basic training at the Great Lakes Training facility and in the Marines at Parris Island.

C. The new FCMs, which have been further revised to be attached to the boot laces, instead of on the side of the boot will arrive. We should receive some of these new devices shortly. The laboratory validation study will be conducted and they will be available for future studies.

V. Months 25-48

A. Shipboard Study

1. The protocol for the Shipboard study was completed.
2. All necessary approvals were obtained.
3. A ship was identified, the Bonhomme Richard
4. Two potential dates were identified, one in November, 1999, and one in December 1999.

B. Marine Basic Training

1. Further discussions were conducted regarding a Marine Basic Training study at Parris Island.
2. We will study overweight and non-overweight women and men undergoing basic training.
3. This study was originally scheduled to occur during the Summer of 2000. However, due to logistical problems, this study has been rescheduled for the Spring of 2001.

C. Planning for the Final Field Study was conducted. This study will be carried out at Fort Jackson.

D. Due to logistical problems that often occur with Military Nutrition research studies, a one year extension was requested, and granted, through 25 October 2001 (See Appendix).

VI. Months 48-60

A. The Marine Basic Training study will be carried out

B. The final Field Study at Fort Jackson will be carried out.

C. Prepare Final Report

A. FIRST FIELD TRAINING STUDY

This study was a combined effort of the Military Nutrition and Biochemistry Division, the Sustainability Directorate and the Science and Technology Directorate of the Natick Research, Development, & Engineering Center (NRDEC), and the Pennington Biomedical Research Center to assess the nutritional adequacy for women of the Meal, Ready-to-Eat ration

during a field training exercise. The study occurred during the field training exercise of a combat service support unit and investigated gender differences in food selection, nutrient intake, and energy expenditure.

TEST VOLUNTEERS

Volunteers were recruited from the 28 Combat Support Hospital (CSH), Fort Bragg, that were engaging in a field training exercise of approximately 14-days duration starting on 1 May 1997. The CSH anticipated deploying almost half of its 520 personnel. This unit strength included 150 women, but did not include approximately 50 FORSCOM nurses that train with the unit. All soldiers from the unit who agreed to participate, except women who were pregnant, were included in the study.

Prior to the start of the study, the subjects were briefed on the nature and purpose of the study and the requirements for participation in the study and were familiarized with the experimental procedures. Subjects were informed verbally and in writing of their rights to withdraw from any part of the study without penalty or prejudice. The Commanding Officer of the prospective volunteers was informed of their responsibilities under AR 70-25 to ensure that the consent of any person under their authority to participate in this research is voluntary. Each subject completed a Volunteer Agreement Affidavit and Volunteer Subject Registry Data Sheet.

All volunteers were asked to participate in all data collection efforts. The volunteers were asked to complete questionnaires providing demographic information, medical history, diet history, nutrition knowledge and attitudes, to record all foods and fluids consumed for a total of seven days, and to record MRE lunches for an additional seven days. Individuals were asked to provide one blood sample and have body height taken once and body weights measured three times. A subsample of 32 volunteers were asked to participate in energy expenditure measures by a stable isotope technique and to wear wristband activity monitors and shoe liner foot contact monitors.

STUDY CONDITIONS

The experimental test period were occur during a routine field training exercise in a temperate environment. The soldiers were provided three MREs per day for seven consecutive days during the field exercise. They were requested to eat no food other than that provided by the study team; however, the investigators were not take any enforcement measures. The importance of this restriction were explained to the CSH personnel at the orientation briefing. Bulk beverages or hot water typically available to combat service support personnel in the field were allowed.

A qualified medical monitor was supplied by the unit and was available during the entire experimental period. The medical monitor was responsible for terminating a volunteer's participation if medically indicated. Appropriate emergency medical service was available at Fort Bragg at all times during all tests.

STUDY DESIGN

The data collection schedule is shown below. An orientation briefing was provided at the beginning of the study. Baseline assessments were conducted at this time. Baseline/descriptive measurements include: height, weight, body composition by skinfold measures, and blood chemistries. Demographics and nutrition knowledge questionnaires and the Diet Habit Survey were administered on the day of baseline measurements.

This collaborative study of women soldiers provided a unique opportunity to study their physiologic responses a multi-stress military training environment. The broad objectives were to: (1) quantitatively determine energy expenditure, and (2) use ambulatory monitoring technologies to make minute-to-minute measurements of soldier activity patterns and the metabolic cost of locomotion.

A. Test volunteers

20 women and 10 men dosed
1 woman and 1 man undosed

30 volunteers, 2/3 female and 1/3 males, received doubly labeled water (DLW). The remaining 2 volunteers served as placebo controls. These subjects collected urine samples (salvia samples not necessary) at the same time as those drinking the DLW dose. This allowed for a correction factor to be calculated for any changes in isotopic baseline that might occur. Subjects were selected to obtain a variety of job classifications (MOS).

B. Experimental design

This study had a repeated measures design in which each test volunteer serves as his own control. The experimental design is outlined in Fig. 1 below.

Figure 1. Schedule of measurements.

	Days																
	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MRE (+/- A-rations)			-	-	-	-	-	-	-	+	+	+	+	+	+	+	
Field training exercise	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
DLW/$^2H_2{}^{18}O$ dose	x																
Saliva samples	x																
Urine samples	x	x	x						x	x	x		x		x	x	x
Food intake				x	x	x	x	x	x	x	x	x	x	x	x	x	
Body composition	x																x
Portable monitors*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

Note: DLW/$^2H_2{}^{18}O$ dose = doubly labeled water, stable isotope labeled hydrogen and oxygen.
*Portable monitors record activity and metabolic cost of locomotion.

PROGRESS

1) Doubly Labeled Water

All urine and saliva samples for the 30 dosed subjects and the 2 placebo subjects have been cleaned and prepared for isotope analyses. Deuterium and ^{18}O analyses are complete. Final calculations of total body water (for EE calculations and for estimation of fat free mass), and total daily energy expenditures have been calculated. Subject characteristics and energy expenditure data are presented in the following table. As expected, the men were heavier, had a higher fat free mass (FFM) and had a higher energy expenditure. This was true over the whole period, as well as before the field training exercise (PreFTX) as well as during the FTX at Camp Mckall. As a first adjustment for the differences in body weight, energy expenditures were simply divided by body weight. When this was done, and this is not necessarily the most appropriate method of adjustment, but it is often done, there are no differences in energy expenditure between the men and women. As expected, energy expenditures during the FTX were higher than that observed pre-FTX.

In addition to including women and men, subjects were selected to obtain a variety of job categories. Our original intent was to have similar breakdowns by job classification. However, we could not locate all of the subjects whom we had selected to obtain equal distributions (of those who had volunteered to participate in the study). We selected subjects from four major MOS groupings: (A) administrative; (M) medical which includes operating room specialists, practical nurses; (M1) Medical Specialists and Medical Lab Specialists; and (S) Utility Equipment Repair, Radio Operator, Medical Equipment Repair, Power Gen. Equipment Repair and Laundry Specialists. The numbers of each by gender, and the energy expenditures are given in the following table (Table 2). Energy expenditure was higher in men than women for each group. In addition, during the FTX, the lowest energy expenditures were observed in the administrative group.

Table 1. Subject characteristics and energy expenditure.

	Female	**Male**
	MEAN ± SE	MEAN ± SE
Age, y	27.2 ± 1.5	28.4 ± 2.5
Body Weight , kg	62.2 ± 2.5	88.2 ±3.8
FFM, kg	45.7 ±1.5	70.5 ±2.2
Energy Expenditure, kcal/d		
PreFTX	2192 ±123	3246 ± 180
FTX	2745 ±122	3959 ± 159
Entire period	2677 ±114	3881 ± 165
Energy expenditure, kcal/d divided by body weight		
PreFTX	37.8 ± 2.1	35.6 ± 1.4
FTX	44.9 ± 1.6	45.5 ± 2.2
Entire period	43.6 ± 1.4	44.4 ± 2.0

Table 2. Pre-field training exercise (FTX) and FTX energy expenditures (kcal/d) by gender and job category groupings.

Group	Male		Female	
	N	Mean ± STD	N	Mean ± STD
PreFTX				
A	1	3300	5	2220 ± 448
M	6	3150 ± 946	7	2372 ± 426
M1	1	3870	4	2614 ± 473
S	1	2729	3	1848 ± 248
FTX				
A	1	3709	4	2332 ± 373
M	6	3880 ± 872	6	2872 ± 229
M1	1	4261	4	2940 ± 268
S	2	4174 ± 431	3	2781 ± 320

A more thorough effort was undertaken to adjust energy expenditures for differences in body weight between the men and women. A more appropriate method than simply dividing energy expenditure by body weight is to use body weight or fat free mass as covariance analysis of variance to adjust for differences in body size. In addition to body weight or fat free mass, we included job classification group, since these were not entirely balanced between the males and females. These adjustments to energy expenditure are given below in Table 3. The adjustments for body weight are somewhat suspect, because most soldiers were in BDUs (Battle Dress Uniform) during the initial weight and we had to adjust the body weights. Therefore, adjustments using FFM (measured from isotope dilution as part of the DLW method) are more likely to be accurate. In addition, although the energy data have been broken down into the short pre-FTX (3 days) and the FTX, the data from the entire period, using linear regression to calculate elimination rates will be the more accurate measure of energy expenditure. Energy expenditure, adjusted for differences in body size and imbalances in MOS group, tended to be higher during the FTX in men compared to women. During the entire period, energy expenditure was significantly higher when adjusting for body weight (which was somewhat suspect) but not when adjusting for fat free mass.

Table 3. Energy expenditures adjusted for differences in body size using covariance analysis or variance.

Adjustments	Female	Male
FTX		
Body Weight	2983 ± 120	3507 ± 186
Body Weight + Group	2987 ± 114	3500 ± 175*
FFM	3058 ± 160	3364 ± 266
FFM + Group	3072 ± 151	3337 ± 251

Pre-FTX		
Body Weight	2393 ± 116	2819 ± 191
Body Weight + Group	2396 ± 118	2812 ± 195
FFM	2531 ± 140	2526 ± 254
FFM + Group	2547 ± 143	2492 ± 260
Entire period, by linear regression		
Body Weight	2907 ± 106	3398 ± 176*
Body Weight + Group	2912 ± 101	3385 ± 168*
FFM	3031 ± 132	3135 ± 240
FFM + Group	3046 ± 124	3102 ± 226

Another way to examine energy expenditure is to plot the individual energy expenditure data points versus fat free mass or body weight. When this is done, the male and female soldiers fall along the same regression line.

2) Activity monitor data

There were no significant differences in Actigraph activity data between males and females. Time spent awake and during sleep, as well as activity events were nearly identical between men and women. The mean daily counts tended to be slightly higher in women (141 vs 131), while the activity events greater than 4 minutes and mean counts during activity tended to be higher in men (5.4 vs 4.6 and 182 vs 130, respectively).

Table 4. Actigraph activity data.

	Females	Males	p
Mean Counts	141 ± 3.3	131 ± 5.5	0.14
Wake, minutes	854 ± 18	850 ± 30	0.90
Sleep, minutes	445 ± 17	489 ± 28	0.19
Sleep latency	26.3 ± 5.5	34.6 ± 94	0.45
Activity events	10.2 ± 0.8	10.2 ± 1.4	0.98
Mean Counts, during activity events	130 ± 21	182 ± 36	0.22
Activity events > 5 minutes	4.6 ± 0.3	5.4 ± 0.5	0.16

Data from the activity monitors was used to develop models to approximate energy expenditure measured by DLW. The first model used calculated RMR (based on FFM, (12) multiplied by waking minutes and the mean activity counts (divided by 100, which approximates a multiple of RMR) plus calculated RMR times sleeping minutes, with the sum divided by 1440 minutes/d. In addition, a further activity factor was added using the activity events multiplied by the mean activity counts during activity events, multiplied by weight, and finally divided by 100.

The second model was much simpler, estimating activity by multiplying body weight by activity events and the mean activity counts during activity events, divided by 100, then adding RMR. The model fit (r2 and p) and energy expenditure for females and males is given below. Although the mean values are very close to the DLW values for energy expenditure, the models explain only 55 and 65 % of the variance. Therefore, further work is needed before Actigraph data can be used to estimate energy utilization.

Model 1

$$\frac{(RMR\ x\ Wake\ x\ mean/100 + RMR\ x\ Sleep)}{1440} + Activity\ Events\ x\ mean\ during\ activity\ x\ weight/100$$

Model 2

$$Activity\ Events\ x\ Mean\ Activity\ Counts\ During\ activity\ x\ weight/100 + RMR$$

	r^2	p	Females	males
Model 1	0.55	0.0001	2890 ± 134	4012 ± 227
Model 2	0.65	0.0001	2610 ± 100	3674 ± 169
DLW			2678 ± 117	3864 ± 192

B. MARINE RECRUIT CRUCIBLE STUDIES

We were very fortunate that the opportunity arose to conduct energy expenditure studies in Marine Recruits undergoing the grueling 54.4 hour Crucible event conducted at Parris Island, South Carolina. This gave us the opportunity to study very high energy expenditures in men and women undergoing the same intense training program. The USARIEM group was asked to conduct cold weather studies in January and February, and I was able to join the team as this project fit perfectly with the aims of this grant. Those individuals who were involved in collecting the data in the field included: James DeLany - PBRC; John Castellani, James Moulton, Kate OBrien, Bill Santee - USARIEM. Since the lead time on the January study was very short, we were not able to use any of the activity monitoring devices. However, we were able to use both the actigraphs, and the new foot contact monitors during the second iteration of the Crucible Studies. Volunteer recruitment was conducted as described under the first field study. The general and detailed study protocols are given below.

STUDY DESIGN/CONDUCT

1. Energy expenditure studies in a subset during two Crucible Studies
   a) 15 men
   b) 10 women

2. Jan-98 Study
   a) Doubly labeled water

b) Weather data
c) Intake measurements

3. Feb-98 Study
    a) DLW
    b) Actigraph data
    c) Foot contact monitor data
    d) Weather data
    e) Intake measurements

- Protocol

    »Baseline Urine Wednesday afternoon

    »DLW dose Wednesday afternoon

    »0200 Thursday Urine

    »2300 Thursday / 0400 Friday Urine

    »2300 Friday Urine

    »0800 Saturday Urine

In addition, a considerable amount of weather information was gathered throughout the studies. Dietary intake was estimated by having the participants save all Meals Ready to Eat (MRE) wrappers in plastic bags, as well as writing any other food eaten, such as the fresh fruits and hot wets that were also provided. The empty wrappers and other foods written down were then used to estimate food intake throughout the study. This process was made somewhat easier because the soldiers only received two MREs throughout the study.

PROGRESS

Isotope analyses have been completed are calculations completed. The calculations for this study were more complicated than those for the first field study because the participants in this study were under fed considerably, and therefore used substantial body stores to make up the caloric deficit. This is important, because in the calculation of energy expenditure from the calculated CO_2 production, one uses a caloric equivalent of CO_2 based on the substrates utilized during the study. Normally, during weight maintenance, that would be equivalent to the dietary intake. However, when substantial body stores are also used for energy, this must be taken into account. The calculations for the food quotient (FQ) used for the DLW calculations are given below. The body weight loss data is given in the Appendix.

The energy expenditures for each of the Crucible studies is given in the following table. The detailed data is presented in the Appendix. As in the previous field study presented above, energy expenditure was significantly higher in men than women. With the results of the two Crucible studies combined (Table below) one can see that the men were considerbly heavier than the women, and had a significantly higher energy expenditure. However, when dividing by body

Parris Island - FQ Calculations - Men

Assume 300g glycogen, 80% fat

Hours	kcal/d	EE total	Intake	Deficit	Fat	Protein	Carb.
54.4	6300	14283	3239	11044	7875	1969	1200
					875	492	300

	Substrate (g)					kcal	total	per g substrate	
								CO2	O2
	diet	body	total	CO2	O2	/L CO2	kcal	formed	used
Prot	101	492.2	593	459	573	5.579	2561	0.774	0.966
CHO	448	300.0	748	620	620	5.047	3130	0.829	0.829
Fat	123	875.0	998	1424	2015	6.629	9441	1.427	2.019
				2503	3208		15132		

RQ	0.780	kcal/L CO2	6.045

Parris Island - FQ Calculations - Women

Assume 240g glycogen, 80% fat

hours	kcal/d	EE total	Intake	Deficit	Fat	Protein	Carbohydrate
54.4	4770	10814	2580	8234	5819	1455	960
					647	364	240

	Substrate (g)					kcal	total	per g substrate	
								CO2	O2
	diet	body	total	CO2	O2	/L CO2	kcal	formed	used
Prot	98	363.7	462	357	446	5.579	1994	0.774	0.966
CHO	400	240.0	640	531	531	5.047	2678	0.829	0.829
Fat	116	646.6	763	1088	1540	6.629	7214	1.427	2.019
				1976	2516		11885		

RQ	0.785	kcal/L CO2	6.014

weight energy expenditures were similar. In addition, when plotting energy expenditure vs. body weight, although there is a great amount of variation around the line, there does not appear to be any difference between men and women. Of interest, and as expected, energy expenditures were much higher in the Crucible studies compared to the combat support hospital study. Energy expenditure in women was nearly 2000 kcal per day higher in this study, and nearly 1000 kcal/d higher than the men in the previous study. Further data analyses need to be performed.

	EE, kcal/d		EE, kcal/kg/d	
	Mean	**SD**	**Mean**	**SD**
JANUARY CRUCIBLE				
Men	6448	868	91.1	15
Women	4800	576	83.5	15
FEBRUARY CRUCIBLE				
Men	5787	1085	80.8	18
Women	4653	725	80.8	18

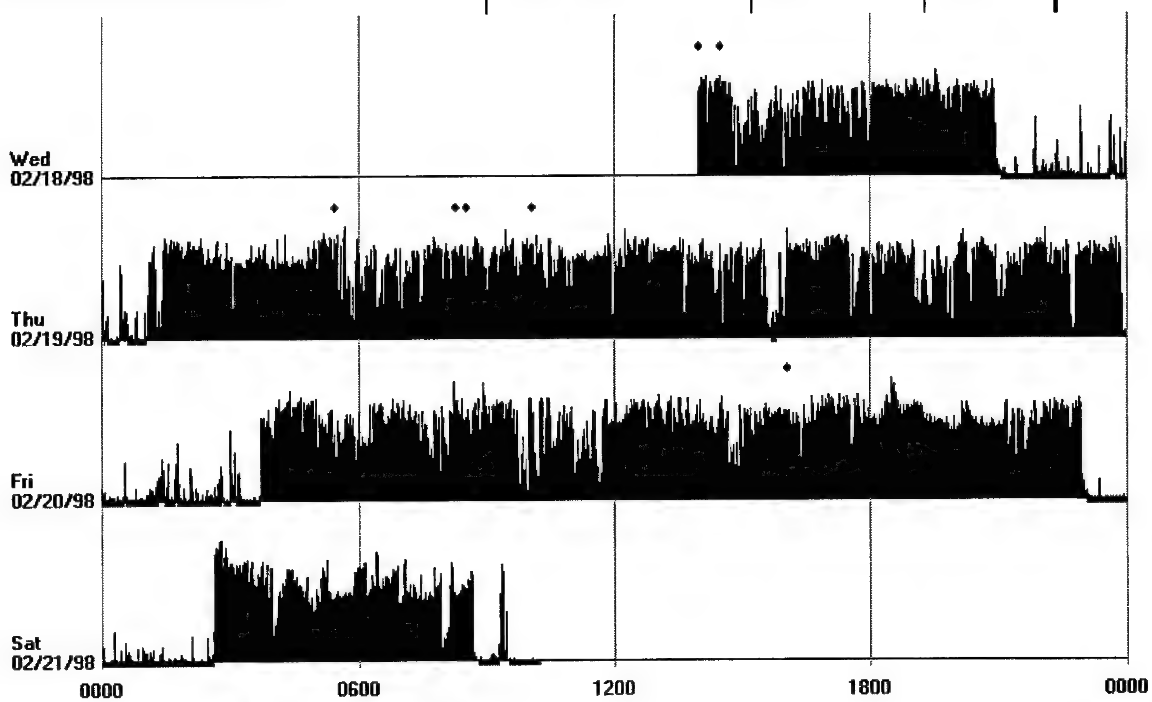
CRUCIBLE DATA COMBINED

	Female	Male	p
Weight, kg	57.8 ± 1.8	72.2 ± 1.5	0.0001
Energy Expenditure, kcal/d	4230 ± 190	6080 ± 160	0.0001
EE/wt (kcal/kg)	83.4 ± 3.7	85.2 ± 3.0	0.72

Analysis of the Actigraph data has been completed and is presented in the following table. The figure below depicts a typical output for the Crucible studies, indicating the little time for sleep in these studies. The mean counts in the Crucible study was considerably higher than that observed in the Combat Support Hospital study, as expected. As in the previous study, there were no differences in counts, activity events, mean counts during activity events, sleep or wake minutes between men and women.

Actigraph Data (per 24 hrs) - Parris Island 2

	Female	Male	p
Mean counts	216 ± 3	212 ± 2	0.26
Mean counts during activity events	348 ± 18	349 ±16	0.98
Wake, minutes	960 ± 5	968 ± 4	0.25
Sleep, min	133 ± 5	126 ± 4	0.25
Counts during activity	348 ± 18	349 ± 16	0.98



C. ENERGY EXPENDITURE OF NAVY WOMEN ONBOARD SHIP

This study is a collaborative effort among NHRC, USARIEM, and the Pennington Biomedical Research Center. With this collaborative effort we will obtain much more information than could have been achieved with the DWHRP grant alone. Information about the energy expenditure and activity patterns, the focus of the DWHRP grant will be obtained, as well as more detailed body composition and nutritional status information that was outside the scope of the DWHRP grant. Kathleen I. Kujawa and James A. Hodgdon, Ph.D. from NHRC will coordinate the shipboard activities and the body composition measurements. The dietary intake information, conducted by USARIEM will be coordinated by MAJ Beverly D. Patton. The biochemical markers of nutritional status will be conducted by Dr. Richard Tulley at the Pennington Biomedical Research Center. The protocol has been approved by the appropriate scientific and Human Use committees.

Beverly Patton, Jim Hodgdon, and Kathleen Kujawa met with the medical officers from the Bonhomme Richard and Amphibious Group 3. Both agreed to support the project. They next briefed their respective bosses (the ship's captain and the admiral in command of Amphib Group 3) and we were given the OK to move forward.

Two possible study dates were identified, 08-19 November or 06-17 December. We are going to try for the November date; that way, if anything falls through at the last moment, we'll still have another opportunity. In fact, we originally planned the study for the December dates, but it did fall through at the last minute. We were fortunate to identify another ship, and conducted the study in February, 2000.

PROTOCOL OBJECTIVE

The objectives of this study are to:

1. To determine the average daily energy expenditure for women while performing various onboard occupational tasks.
2. To obtain information on the nutritional status, including body composition, of female personnel onboard ship.
3. To evaluate the shipboard activity patterns of female Naval personnel.
4. To determine if the nutritional recommendations as outlined in NAVMEDCOMINST 10110.1 are adequate to meet the nutritional needs of female Naval personnel onboard ship.

EXPERIMENTAL METHODS

Subjects

Subjects will be 20 female and 10 male sailors serving aboard a ship homeported in San Diego, CA. Ten women and five men will serve in high physical demand ratings (Physical Demand Ratings (PDR) > 3.0) and ten women and five men will serve in Allow physical demand ratings (PDR < 2.0) (Vickers et al., 1997). It has been shown that PDRs give valid estimates of the

physical demands of Navy enlisted ratings (Carter and Biersner, 1987). All subjects will sign Informed Consent documents prior to their acceptance and participation in the study.

Body Composition

While in port, body composition of all subjects will be determined using the four-compartment body composition technique (Friedl et al., 1992). Body composition assessment will take approximately 3 hr and will occur at the Human Performance Laboratory located in Building 74, Fleet Combat Training Center, Pacific (FCTCPAC), San Diego. The subjects will undergo four different types of tests and will complete a Current Physical Activity Questionnaire. If it is not feasible to do four-compartment body composition (e.g., only available ship is not home-ported in San Diego), body composition will be estimated using the Navy's circumference-based body fat estimation equations (Hodgdon and Beckett, 1984a; 1984b).

Dietary Intake

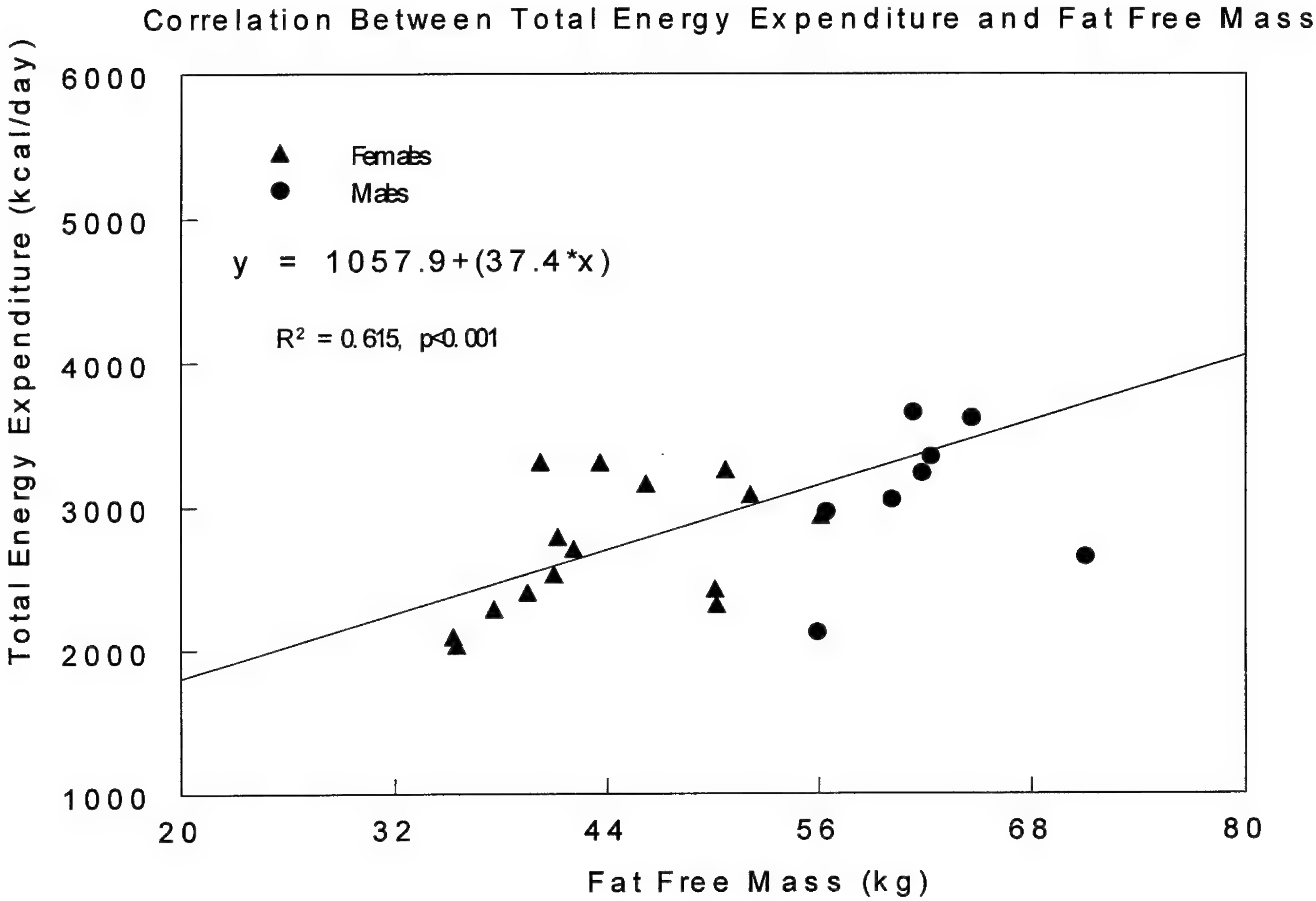
Dietary intake measurements will be obtained both while subjects are in homeport (where subjects are free-living) and while the ship is underway (where dietary choice will be more restricted). Subjects will fill out a food frequency questionnaire while in port to assess usual intake. Aboard ship, food intake will be measured using the visual estimation technique (Rose et al, 1991). This method is comparable in accuracy to the weighing method used for estimating individual dietary intakes (Schnakenberg et al, 1987). Trained recipe specialists will collect information and data on recipe enhancements and recipe preparation in the ship's galley. The nutrient content of foods prepared in the galleys will be calculated with a recipe analysis system developed by the Pennington Biomedical Research Center using military ration nutrient composition data from USARIEM's Military Nutrition & Biochemistry Division database.

PROGRESS

Total body water (TBW) and fat free mass (FFM) were similar regardless of the isotope, ^2H_2O or $H_2{}^{18}O$, from which it was calculated. (Table 1) The females had significantly less TBW and FFM than the males.

Total energy expenditure (TEE) was calculated using a 2 point method and by linear regression of the sample points collected on day 0, 2, 7 and 8. There was no significant difference in TEE regardless of the method by which it was calculated (Table 1). The females expended significantly fewer calories than their male counterparts. There was a significant correlation between total body water and total energy expenditure; the greater the FFM, the more total energy expended (Figure below).

Figure. Correlation between total energy expenditure and fat free mass.



SUMMARY

The average daily energy expenditure of the female subjects was 2808 $\pm$ 429 kcal/day. This is significantly less than the energy expenditure of the male subjects. However, this difference in daily caloric energy expenditure can be explained by a difference in fat free mass. The men had a significantly greater fat free mass than the women.

Table 1. Stable Isotope Data

Subject Number	Total Body Water (kg)		Fat Free Mass (kg)		Energy Expenditure (kcal/d)	
	O^{18}	Deuterium	O^{18}	Deuterium	2 Point Method	Regression Method
Females:						
#101	26.0	26.5	35.5	36.1	2035	2191
#103	25.8	26.1	35.3	35.6	2094	2103
#104	31.9	33.0	43.6	45.1	3310	3372
#105	37.1	37.9	50.7	51.8	3260	2902
#106	30.0	30.5	41.0	41.6	2531	2544
#107	36.6	37.4	50.1	51.1	2427	2676
#108	30.8	31.6	42.1	43.2	2709	2757
#109	33.8	34.3	46.2	46.9	3160	3359
#110	36.8	37.6	50.2	51.4	2317	2281
#111	38.1	38.9	52.1	53.2	3083	3237
#112	30.2	31.0	41.2	42.3	2792	2879
#119	28.9	28.2	39.5	38.6	2403	2508
#120	41.1	40.6	56.1	55.5	2938	3018
#123	29.4	30.0	40.2	41.0	3314	3141
#128	27.5	26.4	37.6	36.1	2287	2443
#113	45.3	43.2	61.8	59.0	3237	3518
Average	33.1	33.3	45.2	45.5	2743.5	2808.1
St Dev.	5.4	5.2	7.4	7.2	437.5	429.2
Males:						
#114	47.3	46.7	64.6	63.7	3617	3769
#116	67.8	66.6	92.7	90.9	4811	4781
#117	41.3	41.3	56.4	56.4	2967	3012
#129	60.6	59.5	82.8	81.3	4536	4623
#131	44.8	47.2	61.3	64.5	3656	3789
#133	44.0	45.7	60.1	62.4	3052	2881
#134	45.6	46.4	62.3	63.4	3351	3358
#135	51.9	52.4	71.0	71.6	2655	2875
#136	40.9	41.6	55.9	56.8	2125	2168
Average	49.4	49.7	67.4	67.9	3418.9	3472.9
St. Dev.	8.7	7.9	11.9	10.8	808.5	806.6

D. MARINE BASIC TRAINING FIELD STUDY

Another joint effort between Dr. DeLany at PBRC and the USARIEM group is being planned. USARIEM personnel met recently with the Marine Recruiting Command. The USARIEM specific tasking is to look at attrition rates of overweight female recruits. The recruits-male and female-are allowed to come in above the screening weight, but DO MEET Marine body fat requirements. Thus, while above weight, they are not above body fat requirements. These individuals participate in all aspects of basic training-unless injured. The goal is, of course, to facilitate adequate weight reduction to meet BOTH the Marine body fat and weight standards by the time the recruit gets to the Crucible. All the recruits are weighed on schedule, and only those overweight are monitored for overweight status. The current commander of the 4th Bn (the female battalion) has made major changes in the dining facility already-the entire bn gets fat modified foods, and those on weight control get a further modified diet. (Pre-prepared low fat meals.)

We have proposed several study aspects:

1) changes in body composition over the course of BCT when the recruits were losing wt (this would be done with DEXA);
2) nutritional status via biochemical measures;
3) calorie and nutrition intake via some method (not visual estimation);
4) energy expenditure and activity patterns (the DWHRP focus) using our current procedures
   a) We propose to study 10 overweight women
   b) 10 "normal" women
   c) 10 men
5) measures of stress via amylase and questionnaire.

Therefore, this study will combine the measures of energy expenditure in men and women undergoing basic training art Parris Island, as well as a study of overweight women undergoing the same training regimen.

This study was originally scheduled to occur during the Summer of 2000. However, due to logistical problems, this study has been rescheduled for the Spring of 2001.

E. ARMY BASIC TRAINING FIELD STUDY – Fort Jackson

Briefing Outline for COL Bednarek:

1. The purpose of this message is seek your guidance and approval for a proposed study of the energy expenditure and activity patterns of men and women participating in Basic Training at Fort Jackson. The basic scientific question being addressed: Do energy expenditure and activity patterns of male and female soldiers differ beyond what would be expected based on differences in body weight?

2. Military relevance: Supports DWHRP and STO H, etc.

3. Study routine:

a. Administration:

- Command brief and coordination - Identify a 10 day period during training that encompasses both less-active and more-active periods. - Brief test volunteers: Command representative informs potential volunteers that the study is important but that participation is entirely voluntary. Potential test volunteers are informed of the scientific purpose of the study, the potential risks and benefits, and the study requirements. They are also informed that they are free to withdraw from the study at any time without prejudice. - Test volunteers sign a volunteer agreement affidavit and fill out a volunteer registry form. - Goal: recruit 20 female and 10 male test volunteers

b. Experimental approach:

- Estimated time committment: One hour to brief potential test volunteers and answer questions. About 6 hours on one morning, followed ~10 min per day to self-collect urine samples.

- Space requirements: Area to measure body weight, and body fat (anthropometry - skin folds/circumferences) of test volunteers. A table, chairs, and 120 V power to weigh water and process saliva and urine samples would be helpful.

- Test routine: At about 0600 on the morning of test Day 0, 20 female and 10 male test volunteers report to designated test area with a sample of their first morning urine collected in pre-issued tubes. They will be asked to not eat anything or put anything in their mouths until later in the morning. After providing a saliva sample, test volunteers will drink about a pint of tap water containing a small amount of naturally-occurring non-radioactive heavy water. The hydrogen and oxygen in heavy water weigh slightly more than usual. The test volunteers will then be weighed and have their body fat estimated by calipers or measuring tape. Each test volunteer will also be issued two small monitors to wear for the 10 day duration of the test: a small activity monitor worn on the wrist, and a small pedometer that attaches to the boot laces. These monitors provide a log of activity patterns and provide information about the metabolic cost of walking and marching. At 3 h and 4 h after drinking the dose of heavy water, each volunteer will be asked to provide saliva samples. The heavy water concentrations in these saliva samples is used to calculate total body water. Once the 4 h saliva is collected, the test volunteers are free to eat and drink. Once each morning on each of the remaining 10 days of the test, each test volunteer provides a urine sample. From the rate of heavy water elimination in the urine, metabolic energy expenditure and water turnover can be accurately determined. Assistance gathering information on the training schedule of the soldiers, including pack weights and periods of marching, would be helpful.

6. Key Research Accomplishments

- Completed Combat Support Hospital Field Training Exercise. This was a fairly low level energy expenditure study showing that men and women undergoing the same FTX show similar energy expenditure when adjusting for differences in body size
- Completed 2 studies in Marine Recruits undergoing the very intense Crucible event. We observed very high energy expenditures in the men and women. Based on activity monitoring, the men and women underwent similar intensity training. When adjusting for differences in body size, the men and women expended similar activities.
- The Shipboard study has been conducted.
- The Marine Basic Training study has been planned at Parris Island. This study will include both overweight and normal weight women, and men undergoing basic training.
- The Army Basic Training Study is being planned for the Summer of 2001.

7. Reportable Outcomes

Tharion, W.J., R.W. Hoyt, N. Hotson, and J.P. DeLany Fluid balance in soldiers during a field training exercise (FTX) of a hospital unit. FASEB J 13:A1052, 1999.

Manuscripts for the Combat Support Hospital study and the Parris Island Crucible studies are under preparation.

8. CONLUSIONS

Overall the field studies have gone very smoothly. We hope that the rest of the studies go as well. When adjusting for differences in body size, the energy expenditure of men and women were similar in the Combat Support Hospital study. Energy expenditures during the short term Crucible studies were very high, possibly some of the highest energy expenditures we will observe. The Crucible studies will provide an excellent paradigm to examine energy expenditures between men and women because all recruits underwent the essentially the same activities and were on the same sleep/wake regimen. When all of the studies are complete, and we can combine all of the data covering a wide range of expenditures, we will be better able to make final conclusions about energy requirements of female military personnel compared to men.

We plan to conduct a study in Marines during basic training at Parris Island and Army Basic Training at Fort Jackson.

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10. Appendices

Appendix 1. Body weight changes and dietary intake for January Crucible Study

January 98 Men, g 101 123 448

		Weight					Women, g	92	105	324
Subj#	Age	Initial	Final	Loss	subj#	Total		PRO	FAT	CHO
1	19	73.2	68.5	4.7	1	5387	3343	544	1595	3388
2	19	65.2	63.0	2.2	2	1980		221	840	945
3	19	64.4	62.3	2.1	3	2084		206	941	1255
4	19	86.0	84.0	2.0	4	2824		447	964	1585
5	18	81.3	77.5	3.8	5	2628		361	1093	1196
6	22	88.1	84.6	3.5	6	2107		398	856	880
7	19	61.4	57.9	3.5	7	3152		590	1253	1354
8	19	84.2	79.7	4.5	8	3218		318	1241	1748
9	25	76.2	74.6	1.6	9	3350		372	1135	1888
10	18	67.3	64.6	2.7	10	4580		430	1431	2778
11	26	80.9	76.8	4.1	11	3293		363	1019	1946
12	19	72.0	68.9	3.1	12	5516		504	1367	3811
13	18	66.4	63.2	3.2	16	2149	2592	336	588	1273
14	19	81.2	76.6	4.6	17	1988		269	968	791
15	19	73.2	70.2	3.0	18	3048		303	1244	1577
16	19	53.4	51.5	1.9	19	3167		312	1040	1832
17	18	63.4	62.2	1.2	21	2403		440	1040	960
18	18	62.1	60.5	1.6	23	2200		340	736	1169
19	20	68.5	67.4	1.1	25	3187		330	979	1809
20	19	46.7	45.6	1.1						
21	19	66.1	64.4	1.7						
22	18	72.9	70.8	2.1						
23	20	44.9	43.4	1.5						
24	19	44.7	42.8	1.9						
25	21	58.7	57.1	1.6						

	PRO	FAT	CHO
Men	396	1145	1898
	99	127	474
Women	333	942	1344
	83	105	336

Appendix 2. Body weight changes and dietary intake for February Crucible Study

February 98

		Weight								
	Age	Initial	Final	Loss	subj#	Total		PRO	FAT	CHO
1	21	72.2	68.0	4.2	1	2995	3135	337	1041	1648
2	19	70.9	67.4	3.5	2	2951		371	1118	1517
3	19	80.0	76.2	3.8	3	3466		425	1122	1929
4	21	80.7	77.5	3.2	4	3919		380	1232	2347
5	20	87.0	84.3	2.7	5	4068		472	1183	2509
6	19	72.7	69.9	2.8	6	3485		602	1333	1603
7	18	67.9	65.6	2.3	7	3443		418	1256	1820
8	21	70.4	67.6	2.8	8	1995		367	619	1008
9	18	85.7	82.6	3.1	9	3195		443	1187	1595
10	19	75.7	73.3	2.4	10	3943		549	1133	2268
11	19	68.2	65.3	2.9	11	1472		131	624	770
12	20	69.1	66.4	2.7	12	2056		436	941	693
13	24	60.8	57.5	3.3	13	3695		459	1238	2007
14	22	65.7	62.9	2.8	14	4716		550	1581	2669
15	22	66.6	63.7	2.9	15	1629		202	535	902
16	19	65.9	64.7	1.2	16	2392	2568	417	700	1282
17	19	65.6	62.6	3.0	17	5227		881	1927	2489
18	18	61.6	60.0	1.6	18	1218		137	483	623
19	23	53.5	51.5	2.0	19	2933		507	1260	1224
20	28	65.5	65.0	0.5	20	2218		441	922	894
21	19	62.2	60.3	1.9	21	1939		249	699	1019
22	23	46.5	44.7	1.8	22	3831		510	1325	2020
23	18	53.6	51.8	1.8	23	2616		441	1049	1175
24	20	59.5	58.5	1.0	24	2022		283	695	1079
25	18	56.9	54.7	2.2	25	1284		160	475	673

	PRO	FAT	CHO
Men	409	1076	1686
	102	120	421

Women	403	954	1248
	101	106	312

Appendix 3. Energy expenditure for Crucible Studies.

Energy Expenditure (EE): Parris Island 1/98 Crucible Study

S#	TBW	KO	KD	EE kcal/d			Body Wt.	kcal/kg		
#1	48.07	0.21465	0.16702	**6937**	**Men**		70.1	99.0		
#2	41.35	0.20148	0.15044	**6532**	**Mean**	**SD**	69.2	94.5		
#3	45.54	0.16409	0.12567	**5350**	**6448**	**868**	78.1	68.5	**91.1**	**15**
#4	52.21	0.16848	0.12623	**6817**			79.1	86.2		
#5	55.99	0.26230	0.21650	**7407**			85.7	86.5		
#6	60.98	0.15041	0.11566	**6464**			71.3	90.7		
#7	39.81	0.12498	0.09135	**4180**			66.8	62.6		
#8	54.18	0.16463	0.12208	**7154**			69.0	103.7		
#9	49.38	0.17743	0.13257	**6854**			84.2	81.5		
#10	43.79	0.14605	0.10587	**5510**			74.5	74.0		
#11	55.67	0.14574	0.10458	**7199**			66.8	107.9		
#12	44.37	0.13718	0.09535	**5888**			67.8	86.9		
#13	46.24	0.12346	0.07934	**6585**			59.2	111.3		
#14	53.10	0.16296	0.12094	**6923**	**Women**		64.3	107.7		
#15	52.12	0.16778	0.12497	**6912**	**Mean**	**SD**	65.2	106.1		
#16	30.99	0.15145	0.09686	**5467**	**4800**	**576**	65.3	83.7	**83.5**	**15**
#17	33.61	0.19337	0.14931	**4507**			64.1	70.3		
#18	33.93	0.20279	0.15102	**5444**			60.8	89.5		
#19	25.10	0.57418	0.51009	**4042**			52.5	77.0		
#20	28.41	0.15200	0.10736	**4006**			65.3	61.4		
#21	37.17	0.14950	0.10536	**5185**			61.3	84.7		
#22	39.09	0.11135	0.06944	**5316**			45.6	116.6		
#23	27.26	0.17041	0.11909	**4433**			52.7	84.1		
#24	28.17	0.15705	0.10773	**4423**			59.0	75.0		
#25	33.77	0.15591	0.10765	**5179**			55.8	92.8		

Average TBW estimated as ½ average body weight loss - body stores used for energy.

Energy Expenditure: Parris Island 2/98 Crucible Study,

S#	TBW	KO	KD	EE kcal/d	Body Wt	kcal/kg
#1	44.74	0.19029	0.14003	**7001**	70.9	98.8
#2	44.07	0.15318	0.10774	**6331**	64.1	98.8
#3	46.73	0.21904	0.17623	**5920**	63.4	93.4
#4	48.18	0.15348	0.11519	**5695**	85.0	67.0
#5	54.75	0.16711	0.12028	**8048**	79.4	101.4
#6	42.45	0.15360	0.10829	**6076**	86.4	70.4
#7	44.14	0.24906	0.19983	**6446**	59.7	108.1
#8	39.09	0.24314	0.21121		82.0	
#9	49.66	0.12981	0.10262	**4050**	75.4	53.7
#10	47.38	0.22328	0.18594	**5058**	66.0	76.7
#11	45.59	0.12737	0.09585	**4431**	78.9	56.2
#12	44.64	0.13038	0.09497	**4942**	70.5	70.1
#13	40.53	0.09639	0.06055	**4709**	64.8	72.7
#14	41.36	0.15649	0.11223	**5753**	78.9	72.9
#15	40.38	0.17042	0.11912	**6562**	71.7	91.5
#16	38.64	0.14845	0.10336	**5524**	52.5	105.3
#17	37.71	0.20600	0.15706	**5656**	62.8	90.1
#18	33.15	0.14191	0.09969	**4426**	61.3	72.2
#19	19.51	0.65661	0.58424	**3530**	68.0	51.9
#20	35.61	0.20896	0.16092	**5214**	46.2	113.0
#21	32.71	0.17785	0.13030	**4850**	65.3	74.3
#22	27.16	0.21229	0.15222	**5127**	71.9	71.4
#23	30.05	0.12875	0.08804	**3897**	44.2	88.3
#24	34.08	0.17554	0.13562	**4139**	43.8	94.6
#25	31.72	0.13451	0.09317	**4164**	57.9	71.9

Men	
Mean	**SD**
5787	**1085**

80.8	**18**

Women	
Mean	**SD**
4653	**725**

83.3	**18**